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U. S. DEPARTMENT OF AGRICULTURE.

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FARMERS' BULLETIN No. 95.

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# GOOD ROADS FOR FARMERS.

BY

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## LETTER OF TRANSMITTAL.

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U. S. DEPARTMENT OF AGRICULTURE,  
OFFICE OF ROAD INQUIRY,  
*Washington, D. C., March 23, 1899.*

SIR: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on the subject of "Good Roads for Farmers," prepared at your direction by Mr. Maurice O. Eldridge, Assistant Director of this Office.

The attempt has been made in preparing this article to present in the plainest possible language the fundamental principles of road building and maintenance, and to furnish instruction and advice to those whose facilities are limited and who are often supplied with but the natural materials.

For the use of cuts Nos. 2, 3, 4, 5, 8, 9, 10, 11, 19, 20, 28, 30, 42, 46, 48, 49, the Office of Road Inquiry is indebted to Mr. Isaac B. Potter, a leading American wheelman.

Respectfully,

ROY STONE, *Director.*

Hon. JAMES WILSON,  
*Secretary of Agriculture.*



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# GOOD ROADS FOR FARMERS.

## INTRODUCTION.

Bad roads constitute the greatest drawback to rural life, and for the lack of good roads the farmers suffer more than any other class. It is obviously unnecessary, therefore, to discuss here the benefits to be derived by them from improved roads. Suffice it to say, that those localities where good roads have been built are becoming richer, more prosperous, and more thickly settled, while those which do not possess these advantages in transportation are either at a standstill or are becoming poorer and more sparsely settled. If these conditions continue, fruitful farms may be abandoned and rich lands go to waste. Life on a farm often becomes, as a result of "bottomless roads," isolated and barren of social enjoyments and pleasures, and country people in some communities suffer such great disadvantage that ambition is checked, energy weakened, and industry paralyzed.

Good roads, like good streets, make habitation along them most desirable; they economize time and force in transportation of products, reduce wear and tear on horses, harness, and vehicles, and enhance the market value of real estate. They raise the value of farm lands and farm products and tend to beautify the country through which they pass; they facilitate rural mail delivery and are a potent aid to education, religion, and sociability. Charles Sumner once said, "The road and the schoolmaster are the two most important agents in advancing civilization."

The difference between good and bad roads is often equivalent to the difference between profit and loss. Good roads have a money value to farmers as well as a political and social value, and leaving out convenience, comfort, social and refined influences which good roads always enhance, and looking at them only from the "almighty dollar" side, they are found to pay handsome dividends each year.

People generally are beginning to realize that road building is a public matter, and that the best interests of American agriculture and the American people as a whole demand the construction of good roads, and that money wisely expended for this purpose is sure to return.

## PRINCIPLES WHICH SHOULD GOVERN LOCATION AND TREATMENT OF ROADS.

Road making is perfected by practice, experience, and labor. Soils and clays, sand and ores, gravels and rocks, are transformed into beautiful roads, streets, and boulevards, by methods which conform with their great varieties of characters and with nature's laws. The art of road building depends largely for its success upon its being carried on in conformity with certain general principles.

It is necessary that roads should be hard, smooth, comparatively level, and fit for use at all seasons of the year; that they should be properly located, or laid out on the ground, so that their grades may be such that animate or inanimate power may be applied upon them to the best advantage and without great loss of energy; that they

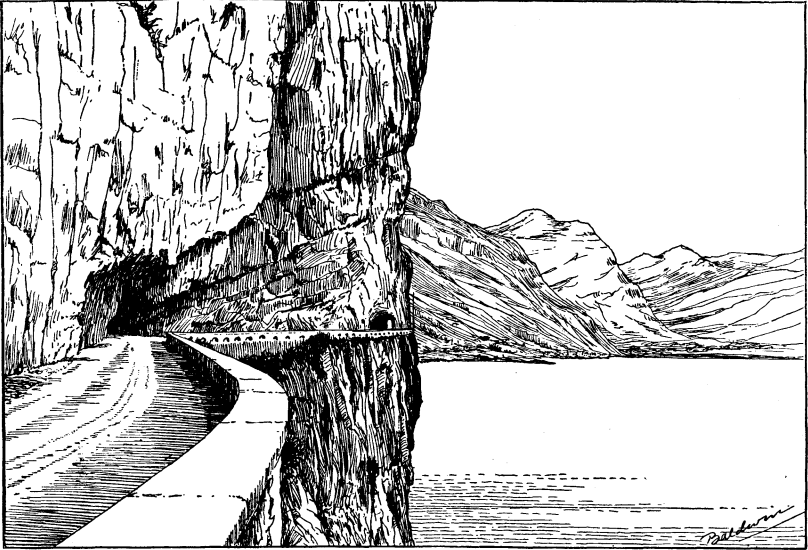


FIG. 1.—Grand view of the Axenstrasse as it skirts the bay of Uri near Fluelen in the Alps of Switzerland.

should be properly constructed, the ground well drained, the roadbed graded, shaped, and rolled, and that they should be surfaced with the best material procurable; that they should be properly maintained or kept constantly in good repair.

All the important roads in the United States can be and doubtless will be macadamized or otherwise improved in the not distant future. This expectation should govern their present location and treatment everywhere. Unless changes are made in the location of the roads in many parts of the country it would be worse than folly to macadamize them. "Any costly resurfacing of the existing roads will fasten them where they are for generations," says General Stone. The chief diffi-

culty in this country is not with the surface, but with the steep grades, many of which are too long to be reduced by cutting and filling on the present lines, and if this could be done it would cost more in many cases than relocating them.

Many of our roads were originally laid out without any attention to general topography, and in most cases followed the settler's path from cabin to cabin, the pig trail, or ran along the boundary lines of the farms regardless of grades or direction. Most of them remain to-day where they were located years ago, and where untold labor, expense, and energy have been wasted in trying to haul over them and in endeavors to improve their deplorable condition.

The great error is made of continuing to follow these primitive paths with our public highways. The right course is to call in an engineer and throw the road around the end or along the side of steep hills (fig. 1) instead of continuing to go over them; or to pull the road up on dry solid ground instead of splashing through the mud and water of the creek or swamp. Far more time and money have been wasted in trying to keep up a single mile of one of these "pig-track" surveys than it would take to build and keep in repair two miles of good road.

Another and perhaps greater error is made by some persons in the West who continue to lay out their roads on "section lines." These sections are all square, with sides running north, south, east, and west. A person wishing to cross the country in any other than these directions must necessarily do so in rectangular zigzags. It also necessitates very often the crossing and recrossing of hills and valleys, which might be avoided if the roads had been constructed on scientific principles.

In the prairie State of Iowa, for example, where roads are no worse than in many other States, there is a greater number of roads having much steeper grades than are found in the mountainous Republic of Switzerland. In Maryland the old stagecoach road or turnpike running from Washington to Baltimore makes almost a "bee line," regardless of hills or valleys, and the grades at places are as steep as 10 or 12 per cent, where by making little detours the road might have been made perfectly level, or by running it up the hills less abruptly the grade might have been reduced to 3 or 4 per cent, as is done in the hilly regions of many parts of this and other countries (fig. 2). Straight roads are the proper kind to have, but in hilly countries their straightness should always be sacrificed to obtain a level surface so as to better accommodate the people who use them.

Graceful and natural curves conforming to the lay of the land add beauty to the landscape, besides enhancing the value of property. Not only do level curved roads add beauty to the landscape and make lands along them more valuable, but the horse is able to utilize his full strength over them (fig. 3); furthermore a horse can pull only four-fifths as much on a grade of 2 feet in 100 feet, and this gradually lessens

until with a grade of 10 feet in 100 feet he can draw but one-fourth as much as he can on a level road.

Good roads should therefore wind around hills instead of running over them, and in many cases this can be done without greatly increasing the distance. To illustrate, if an apple or pear be cut in half and one of the halves placed on a flat surface, it will be seen that the horizontal distance around from stem to blossom is no greater than the distance over between the same points.

The willfulness of one or two private individuals sometimes becomes a barrier to traffic and commerce. The great drawback to the laying out of roads on the principle referred to is that of the necessity, in some cases, of building them through the best lands, the choicest pastures and orchards, instead, as they do now, of cutting around the farm line or passing through old worn-out fields or over rocky knolls. But if farmers wish people to know that they have good farms, good

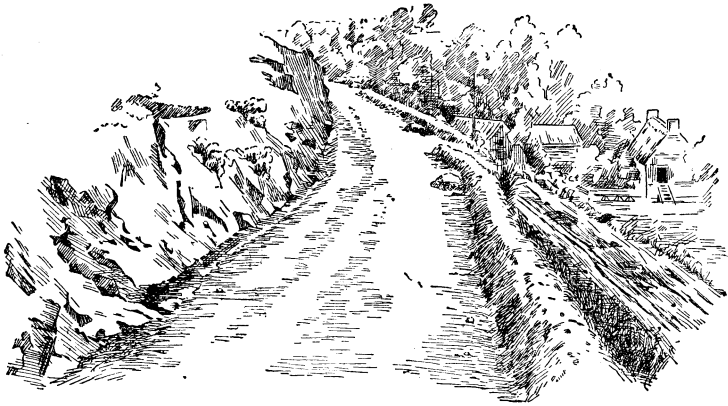


FIG. 2.—Macadam road in Italy showing manner of location and construction of road running around a hill.

cattle, sheep, or horses, good grain, fruit, or vegetables, they should let the roads go through the best parts of the farms.

The difference in length between a straight road and one which is slightly curved is less than one would imagine. Says Sganzin: "If a road between two places 10 miles apart were made to curve so that the eye could see no farther than a quarter of a mile of it at once, its length would exceed that of a perfectly straight road between the same points by only about 150 yards." Even if the distance around a hill be much greater, it is often more economical to construct it that way than to go over and necessitate the expenditure of large amounts of money in reducing the grade, or a waste of much valuable time and energy in transporting goods that way. Gillespie says "that, as a general rule, the horizontal length of a road may be advantageously increased to avoid an ascent by at least twenty times the perpendicular height which is thus to be avoided—that is, to escape a hill 100 feet high, it

would be proper for the road to make such a circuit as would increase its length 2,000 feet." The mathematical axiom that "a straight line is the shortest distance between two points" is not, therefore, the best rule to follow in laying out a road; better is the proverb that "the longest way round is the shortest way home."

### GRADES.

The grade is the most important factor to be considered in the location of roads. The smoother the road surface, the less the grade should be.

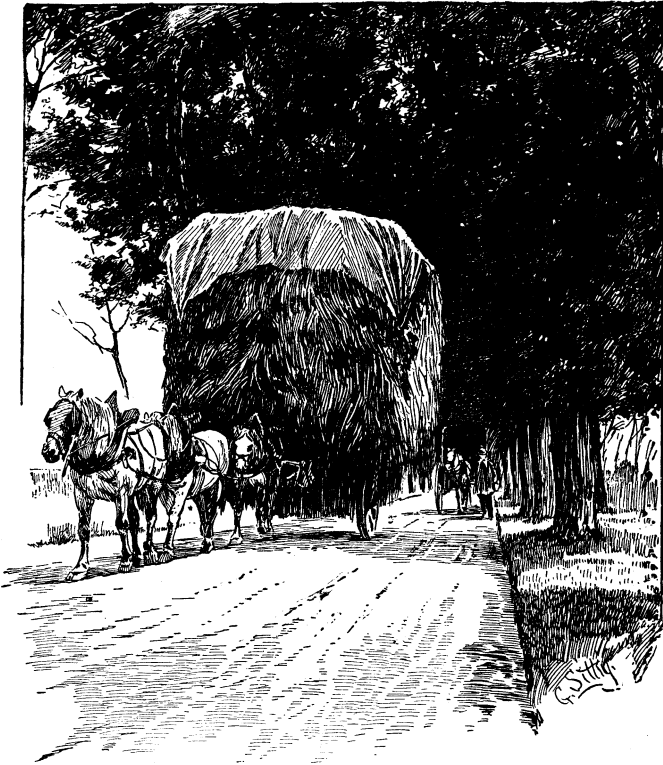


FIG. 3.—Hauling hay to market over a level road in Normandy, France. This load weighs upward of 4 tons. The road is always kept smooth and hard, making the markets always accessible (drawn from photograph).

Whether the road be constructed of earth, stone, or gravel, steep grades should always be avoided if possible. They become covered at times with coatings of ice or slippery soil, making them very difficult to ascend with loaded vehicles as well as dangerous to descend. They allow water to rush down at such a rate as to wash great gaps alongside or to carry the surfacing material away. As the grade increases in steepness either the load has to be diminished in proportion or more

horses or power attached. From Gillespie we find that if a horse can pull on a level 1,000 pounds, on a rise of—

| 1 foot in—              | Pounds. |
|-------------------------|---------|
| 100 feet he draws ..... | 900     |
| 50 feet.....            | 810     |
| 44 feet.....            | 750     |
| 40 feet.....            | 720     |
| 30 feet.....            | 640     |
| 25 feet.....            | 540     |
| 24 feet.....            | 500     |
| 20 feet.....            | 400     |
| 10 feet.....            | 250     |

It is therefore seen that when the grades are 1 foot in 44 feet or 120 feet to the mile a horse can only draw three-fourths as much as he can on a level; where the grade is 1 foot in 24 feet, or 220 feet to the mile, he can draw only one-half as much, and on a 10 per cent grade, or 520 feet to the mile, he is able to draw only one-fourth as much as on a level road.

As a chain is no stronger than its weakest link, just so the greatest load which can be hauled over a road is the load which can be hauled through the deepest mud hole or up the steepest hill on that road. The cost of haulage is, therefore, necessarily increased in proportion to the roughness of the surface or steepness of the grade. It costs one and one-half times as much to haul over a road having a 5 per cent grade and three times as much over one having a 10 per cent grade as on a level road. As a perfectly level road can seldom be had, it is well to know the steepest allowable grade. If the hill be one of great length, it is best to have the lowest part steepest, upon which the horse is capable of exerting his full strength, and to make the slope more gentle toward the summit, to correspond with the continually decreasing strength of the fatigued animal.

So far as descent is concerned, a road should not be so steep that the wagons and carriages can not be drawn down it with perfect ease and safety. Sir Henry Parnell considered that when the grade was no greater than 1 foot in 35 feet vehicles could be drawn down it at a speed of 12 miles an hour with perfect safety. Gillespie says:

It has been ascertained that a horse can for a short time double his usual exertion; also, that on the best roads he exerts a pressure against his collar of about one thirty-fifth of the load. If he can double his exertion for a time, he can pull one thirty-fifth more, and the slope which would force him to lift that proportion would be, as seen from the above table, one of 1 in 35, or about a 3 per cent grade. On this slope, however, he would be compelled to double his ordinary exertion to draw a full load, and it would therefore be the maximum grade.

#### DRAINAGE.

Mr. Isaac B. Potter, an eminent authority upon roads, says:

Dirty water and watery dirt make bad going, and mud is the greatest obstacle to the travel and traffic of the farmer. Mud is a mixture of dirt and water. The dirt

is always to be found in the roadway, and the water, which comes in rain, snow, and frost, softens it; horses and wagons and narrow-wheel tires knead it and mix it, and it soon gets into so bad a condition that a fairly loaded wagon can not be hauled through it.

We can not prevent the coming of this water, and it only remains for us to get rid of it, which can be speedily done if we go about it in the right way. Very few people know how great an amount of water falls upon a country road, and it may surprise some of us to be told that on each mile of an ordinary country highway 3 rods wide within the United States there falls each year an average of 27,000 tons of water. In the ordinary country dirt road the water seems to stick and stay as if there was no other place for it, and this is only because we have never given it a fair opportunity to run out of the dirt and find its level in other places. We can not make a hard road out of soft mud, and no amount of labor and machinery will make a good dirt road that will stay good unless some plan is adopted to get rid of the surplus water. (Fig. 4.) Water is a heavy, limpid fluid, hard to confine and easy to let loose. It is always seeking for a chance to run down a hill; always trying to find its lowest level.

An essential feature of a good road is good drainage and the principles of good drainage remain substantially the same, whether the

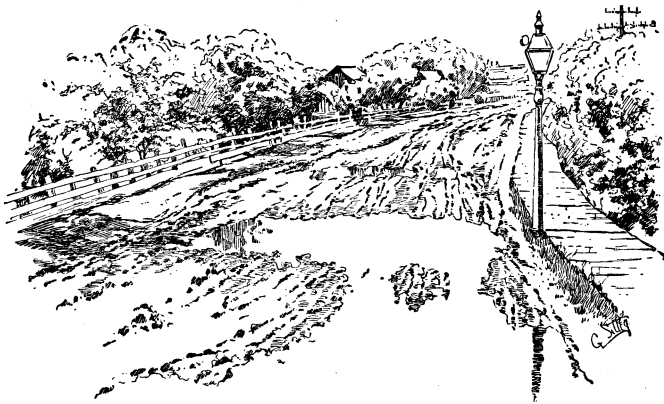


FIG. 4.—Surplus water lying in country road after a heavy shower, indicating lack of proper methods of drainage (drawn from photograph).

road be constructed of earth, gravel, shells, stones, or asphalt. The first demand of good drainage is to attend to the shape of road surface. This must be “crowned,” or rounded up toward the center, so that there may be a fall from the center to the sides, thus compelling the water to flow rapidly from the surface into the gutters which should be constructed on one or both sides, and from there in turn be discharged into larger and more open channels. Furthermore, it is necessary that no water be allowed to flow across a roadway; culverts, tile, stone, or box drains should be provided for that purpose.

In addition to being well covered and drained, the surface should be kept as smooth as possible, that is, free from ruts, wheel tracks, holes, or hollows. If any of these exist, instead of being thrown to the side the water is held back and is either evaporated by the sun or absorbed

by the material of which the road is constructed. In the latter case the material loses its solidity, softens and yields to the impact of the horses' feet and the wheels of vehicles, and, like the water poured upon a grindstone, so the water poured on a road surface which is not properly drained assists the grinding action of the wheels in rutting or completely destroying the surface. When water is allowed to stand on a road the holes and ruts rapidly increase in number and size; wagon after wagon sinks deeper and deeper, until the road finally becomes utterly bad (fig. 5), and sometimes impassable, as frequently found in many parts of the country during the winter season.

Road drainage is just as essential to a good road as farm drainage is to a good farm. In fact, the two go hand in hand, and the better the one the better the other, and vice versa. There are thousands of miles of public roads in the United States which in the month of February

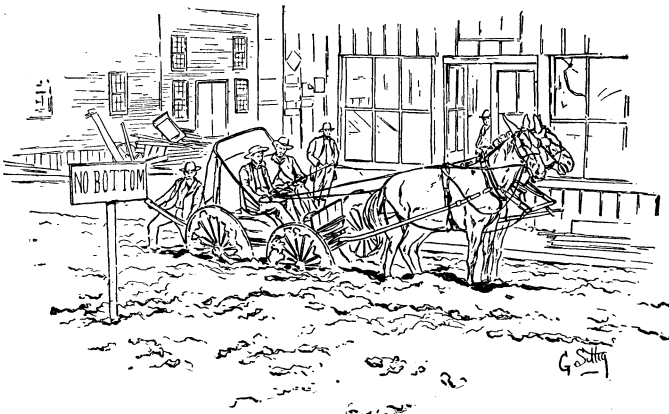


FIG. 5.—Scene in country town in the Spring of 1892 (drawn from photograph,

are practically impassable because of bad drainage, while for the same reason thousands of acres of the richest meadow and swamp lands lie idle from year in to year out.

**Surface Drainage.**—The wearing surface of a road must be in effect a roof; that is, the section in the middle should be the highest part and the traveled roadway should be made as impervious to water as possible, so that it will flow freely and quickly into the gutters or ditches alongside (fig. 6). The best shape for the cross section of a road has been found to be either a flat ellipse or one made up of two plane surfaces sloping uniformly from the middle to the sides and joined in the center by a small, circular curve. Either of these sections may be used, provided it is not too flat in the middle for good drainage or too steep at the gutters for safety. The steepness of the slope from the center to the sides should depend upon the nature of the surface, being greater or less according to its roughness or smoothness. This slope ought to be greatest on earth roads, perhaps as much in some cases as 1 foot in

20 feet after the surface has been thoroughly rolled or compacted by traffic. This varies from about 1 in 20 to 1 in 30 on a macadam road to 1 in 40 or 1 in 60 on the various classes of pavements and for asphalt sometimes as low as 1 in 80.

Where the road is constructed on a grade or hill the slope from the center to the sides should be slightly steeper than that on the level road. The best cross section for roads on grades is the one made up from two plane surfaces sloping uniformly from the center to the sides. This is done so as to avoid the danger of overturning near the side ditches, which would necessarily be increased if the elliptical form were used. The slope from the center to the sides must be steep enough to lead the water into the side ditches instead of allowing it to run down the middle of the road. Every wheel track on an inclined roadway becomes a channel for carrying down the water,

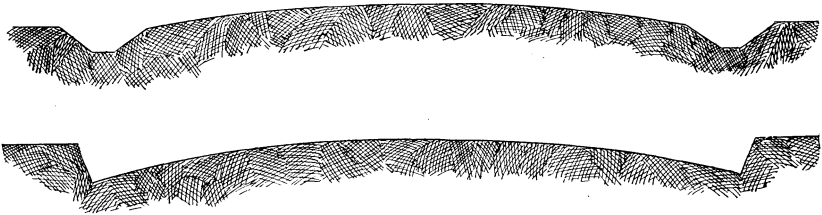


FIG. 6.—Cross sections of two good forms for earth roads. The lower section can be made with a road machine and both sections can be rolled and constructed so that water will run off easily and quickly.

and unless the curvature is sufficient these tracks are quickly deepened into water courses which cut into and sometimes destroy the best improved road.

#### WATER BREAKS.

In order to prevent the washing out of earth roads on hills it sometimes becomes necessary to construct water breaks; that is, broad shallow ditches arranged so as to catch the surface water and carry it each way into the side ditches. Such ditches retard traffic to a certain extent, and often result in overturning vehicles; consequently they should never be used until all other means have failed to cause the water to flow into the side channels; neither should they be allowed to cross the entire width of the road diagonally, but should be constructed in the shape of the letter V. This arrangement permits teams following the middle of the road to cross the ditch squarely and thus avoid the danger of overturning. These ditches should not be deeper than are absolutely necessary to throw the water off the surface, and the part in the center should be the shallowest.

Unfortunately farmers and road masters have a fixed idea that the one way to prevent hills, long and short, from washing is to heap upon them quantities of those original tumular obstructions known indiffer-

ently as "thank-you-ma'ams," "breaks," or "hummocks," and the number they can squeeze in upon a single hill is positively astonishing.

### SIDE DITCHES.

Quoting Mr. Isaac B. Potter—

Side ditches are necessary because the thousands of tons of water which fall upon every mile of country road each year, in the form of rain or snow, should be carried



FIG. 7.—Roadside ditch dug by erosion.

away to some neighboring creek or other water channel as fast as the rain falls and the snow melts, so as to prevent its forming mud and destroying the surface of the road. When the ground is frozen and a heavy rain or sudden thaw occurs the side ditch is the only means of getting rid of the surface water, for no matter how sandy or porous the soil may be, when filled with frost it is practically water tight, and the water which falls or forms on the surface must either remain there or be carried away by surface ditches at the sides of the road.

A side ditch should have a gradually falling and even grade at the bottom, and broad, flaring sides to prevent the caving in of its banks. It can be easily cleared of snow, weeds, and rubbish; the water will run into it easily from each side, and it is not dangerous to wagons and foot travelers. It is, therefore, a much better ditch

than the one shown in fig. 7, which represents the kind of ditch very often dug along the country roadside.

Where the road is built on a grade some provision should be made to prevent the wash of the gutters into great, deep gullies, such as is seen in fig. 7. This can be done by paving the bottom and sides of the gutters with brick, river rocks, or field stone. In order to make the flow in such side ditches as small as possible it is advisable to construct outlets into the adjacent fields or to lay underground pipes or tile drains with openings into the ditches at frequent intervals.

The size of side ditches should depend upon the character of the soil and the amount of water they are expected to carry. If possible they should be located 3 feet from the edge of the traveled roadway, so that if the latter is 14 feet wide there will be 20 feet of clear space between ditches.

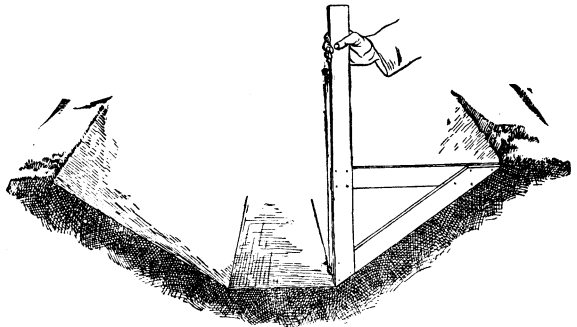


FIG. 8.—Proper form of surface ditch, showing manner of construction.

To make a ditch with even, flaring sides (fig. 8), so as to produce a neat job, it is good policy to use a rough gauge, like that shown in fig. 8. The

gauge is made of light strips of wood about 3 inches in width and 1 inch thick. The upright strip should be about 4 feet long and the horizontal strip should be 18 inches in length, measured from the left side of the upright piece to the point of the gauge on the extreme right. The top of the horizontal strip should be 1 foot from the bottom point of the gauge. This gauge should be provided with a plumb and line, and by means of the upright strip is held vertical while the slope is made to correspond with the edges of the diagonal strip.

The bottom of the ditch may vary in width from 3 to 12 inches, or even more, as may be found necessary in order to carry the largest amount of water which is expected to flow through it at any one time. Sometimes the only ditches necessary to carry off the surface water are those made by the use of the road machines or road graders. The blade of the machine may be set at any desired angle, and when drawn along by horses cuts into the surface and moves the earth from the sides toward the center, forming gutters alongside and distributing the earth uniformly over the traveled way (fig. 23). Such gutters are liable to become clogged by brush, weeds, and other debris, or destroyed by passing wagons, and it is therefore better, when the space permits, to have the side ditches above referred to, even if the road be built with a road machine.

#### SUBDRAINAGE.

In order to have a good road it is just as necessary that water should not be allowed to attack the substructure from below as that it should not be permitted to percolate through it from above. Especially is the former provision essential in cold climates, where, if water is allowed to remain in the substructure the whole roadway is liable to become broken up and destroyed by frost and the wheels of vehicles. Therefore, where the road runs through low wet lands or over certain kinds of clayey soils surface drainage is not all that is necessary. Common side drains catch surface water and surface water only. Isaac Potter says:

Many miles of road are on low, flat lands and on springy soils, and thousands of miles of prairie roads are, for many weeks in the year, laid on a wet subsoil. In all such cases, and, indeed, in every case where the nature of the ground is not such as to insure quick drainage, the road may be vastly benefited by under drainage. An under drain clears the soil of surplus water, dries it, warms it, and makes impossible the formation of deep, heavy, frozen crusts, which are found in every undrained road when the severe winter weather follows the heavy fall rains. This frost causes nine-tenths of the difficulties of travel in the time of sudden or long-continued thaws.

Roads constructed over wet undrained lands are always difficult to manage and expensive to maintain, and they are liable to be broken up in wet weather or after frosts. It will be much cheaper in the long run to go to the expense of making the drainage of the subjacent soil and substructure as perfect as possible. There is scarcely an earth road in the United States which can not be so improved by surface or subdrainage as to yield benefits to the farmers a hundred times greater in value than the cost of the drains themselves.

Under drains are not expensive. On the contrary, they are cheap and easily made, and if made in a substantial way and according to the rules of common sense a good under drain will last for ages. Use the best tools and materials you can get (figs. 9 and 10); employ them as well as you know how, and wait result with a clear conscience. Slim fagots of wood bound together and laid lengthwise at the bottom of a



FIG. 9.—Miles's drainage scoop for preparing bottom of ditch for the tile drains.

carefully graded drain ditch will answer fairly well if stone or drain tile can not be had, and will be of infinite benefit to a dirt road laid on springy soils.

Subdrains should be carefully graded with a level (fig. 11) at the bottom to a depth of about 4 feet, and should have a continuous fall throughout their entire length of at least 6 inches for each 100 feet in length. If tile drains (fig. 12) can not be had, large, flat stones may be carefully placed so as to form a clear, open passage at the bottom for the flow of the water (fig. 13). The ditch should then be half filled with rough field stones, and on these a layer of smaller stones or gravel and a layer of sod, hay, gravel, cinders, or straw, or, if none of these can be had, of soil. If field stones or drain tile can not be procured,

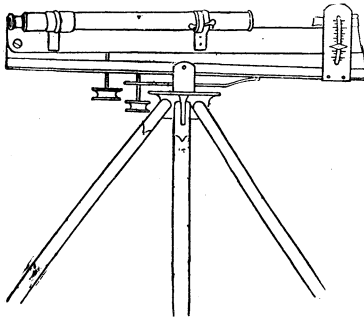


FIG. 11.—Harris's grade level which can be used by any farmer or road builder in establishing grades for roadways or in constructing surface drains or subdrains for roads or farms.

satisfactory results may be attained by the use of logs and brush, as seen in fig. 14.

If there be springs in the soil which might destroy the stability of the road, they should, if possible, be tapped and the water carried under or along the side until it can be turned away into some side channel. Such drains may be made of bundles of brush (fig. 15), field stones (fig. 16), brick (fig. 17), or drain tiles. They should be so protected by straw, sod, or brush as to prevent the soil from washing in and clogging them.

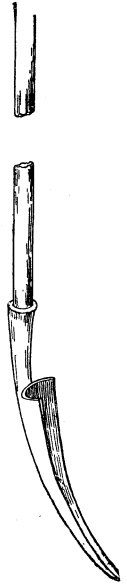


FIG. 10.—Instrument used for grading subdrain ditch to receive tile.

## DIFFERENT KINDS OF ROADS.

Most of the roads in this country are of necessity constructed of earth, while in a few of the richer and more enterprising communities the most important thoroughfares are surfaced with gravel, shell, stones, or other materials. Unless some new system for the improvement of public roads is adopted, the inability of rural communities to

raise funds for this purpose will necessarily cause the construction of hard roads to be very gradual for some time to come. Until this new system is adopted the most important problem will be that of making the most of the roads which

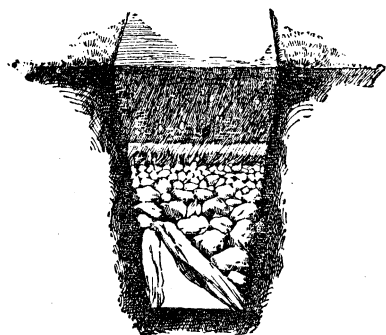


FIG. 13.—Subdrain made with field stones.

exist, rather than building new ones of specially prepared materials. The natural materials and the funds already available must be used with skill

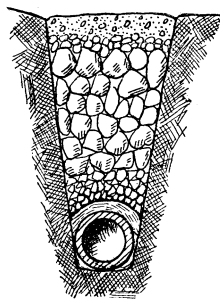


FIG. 12.—Subdrain constructed with drain tile and stone.

and judgment in order to secure the best results. The location, grades, and drainage having been treated in the preceding pages, the next and most important consideration is that of constructing and improving the various kinds of roads.

#### EARTH ROADS.

Of earth roads, as commonly built, it suffices to say that their present conditions should not be tolerated in communities where there are any other materials with which to improve them. Earth is the poorest of all road materials, aside from sand, and earth roads require more attention than any other kind of roads, and as a rule get less. At best, they possess so many defects that they should have all the attention and care of which their condition is susceptible. With earth alone, however, a very passable road can be made, provided the principles of location, drainage, and shape of sur-

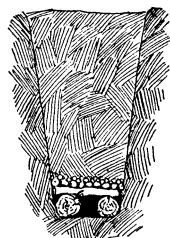


FIG. 14.—Subdrain constructed of logs and fagots of wood.

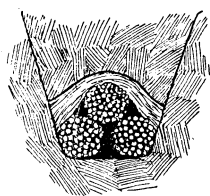


FIG. 15.—Subdrain made of bundles of brush for conveying spring water under or alongside roads.

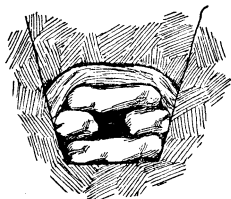


FIG. 16.—Subdrain made of field stone for conveying spring water under or alongside of roads.

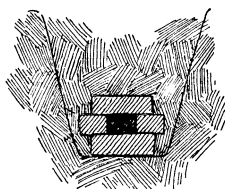


FIG. 17.—Subdrain made of bricks for conveying spring water under or alongside of roads.

face, together with that of keeping the surface as smooth and firm as possible by rolling, be strictly adhered to. In fact a good earth road

is second to none for summer travel and superior to many of the so-called macadam or stone roads.

**Drainage.**—"Water is the great road destroyer," and too much attention can not be given to the surface and subdrainage of earth roads.



FIG. 18.—Cross section of a 14-foot road showing the result of improper construction and drainage. Note that the center of the road has become the lowest part and that water may collect on the surface, making the road practically impassable.

(fig. 18). The material of which their surfaces are composed is more susceptible to the action of water and more easily destroyed by it than any other highway material. Drainage alone will often change a bad road into a good one, while on the other hand the best road may be destroyed by the absence of good drains.

**Rolling.**—The same can be said of rolling, which is a very important matter in attempting to build or maintain a satisfactory earth road. If loose earth is dumped into the middle of the road and consolidated by traffic, the action of the narrow-tired wheels cuts it or rolls it into uneven ruts and ridges, which hold water, and



FIG. 19.—Section of loose unrolled earth road.

ultimately results, if in the winter season, in a sticky, muddy surface, or if it be in dry weather, in covering the surface with several inches of dust. If, however, the surface be prepared with a road machine and properly rolled with a heavy roller, it can usually be made sufficiently firm and smooth to sustain the traffic without rutting, and resist the penetrating action of the water. Every road is made smoother, harder, and better by rolling (figs. 19 and 20).

Such rolling should be done in damp weather, or if that is not possible, the surface should be sprinkled if the character of the soil requires such aid for its proper consolidation.

**Construction.**—In constructing new earth roads all stumps, brush, vegetable matter, rocks, and boulders should be removed from the surface and the resulting holes filled in with suitable material, carefully and thoroughly tamped or rolled, before the road embankment is commenced. No perishable material should be used in forming the permanent embankments. Where possible the longitudinal grade should be kept down to 1 foot in 30 feet, and should under no circumstances exceed 1 in 20, while that from center to sides should be maintained at 1 foot in 20 feet.

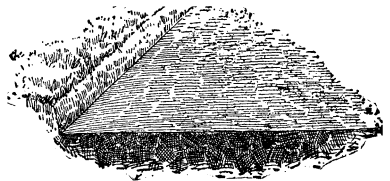


FIG. 20.—Section of compact, smooth earth road made solid by use of roller.

Wherever the subgrade soil is found unsuitable it should be removed and replaced with good material rolled to a bearing, i. e., so as to be smooth and compact. The roadbed having been brought to the required grade and crown, should be rolled several times to compact the surface. All inequalities discovered during the rolling should be leveled up and rerolled. On the prepared subgrade the earth should be spread, harrowed if necessary, and then rolled to a bearing by passing the unballasted road roller a number of times over every portion of the surface of the section.

In level countries and with narrow roads, enough material may be excavated to raise the roadway above the subgrade in forming the side ditches by means of road machines. If not, the required earth should be obtained by widening the side excavations, or from cuttings on the line of the new roadway, or from pits close by, elevating graders and modern dumping or spreading wagons being preferably used for this purpose. When the earth is brought up to the final height, it is again harrowed, then trimmed by means of road levelers or road machines, and ultimately rolled to a solid and smooth surface with road rollers gradually increased in weight by the addition of ballast.

No filling should be brought up in layers exceeding 9 inches in depth. During the rolling, sprinkling should be attended to whenever the character of the soil requires such aid. The cross section of the roadway must be maintained during the last rolling stage by the addition of earth as needed. On clay soils a layer of sand, gravel, or ashes spread on the roadway will prevent the sticking of the clay to the roller. As previously explained, the finishing touches to the road surface should be given by a heavy roller. (Fig. 21.)

Before the earth road is opened to traffic, deep and wide side ditches, like that seen in fig. 8, should be constructed, with a fall throughout their entire length of at least 1 in 120. They should be cleaned and left with the drain tiling connections, if any, in good working order.

Clay soils, as a rule, absorb water quite freely and soften when saturated, but water does not readily pass through them; hence they are not easily subdrained. When used alone, clay is the least desirable of all road materials, but roads constructed over clay soils may be treated with sand or small gravel, from which a comparatively hard and compact mass is formed which is nearly impervious to water. Material of this character found in the natural state, commonly known as hardpan, makes, when properly applied, a very solid and durable surface. In soil composed of a mixture of sand, gravel, and clay all that is neces-

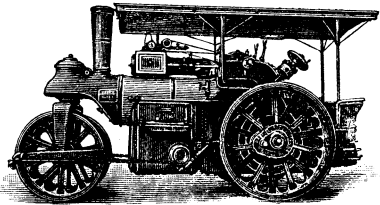


FIG. 21.—Russell steam road roller built in all sizes and can be used for rolling roads, crushing stone, sawing wood, thrashing, etc.

sary to make a good road of its kind is to "crown" the surface, keep the ruts and hollows filled, and the ditches open and free.

**Filling the ruts.**—Roads are prone to wear in ruts, and when hollows and ruts begin to make their appearance on the surface of an earth road, great care should be used in selecting new material with which they should be immediately filled, because a hole which could have been filled at first with a shovel full of material would soon need a cart full. It should, if possible, be of a gravelly nature, entirely free from vegetable earth, muck, or mold. Sod or turf should not be placed on the surface, neither should the surface be renewed by throwing upon it the wornout material from the gutters alongside. This last injunction, if

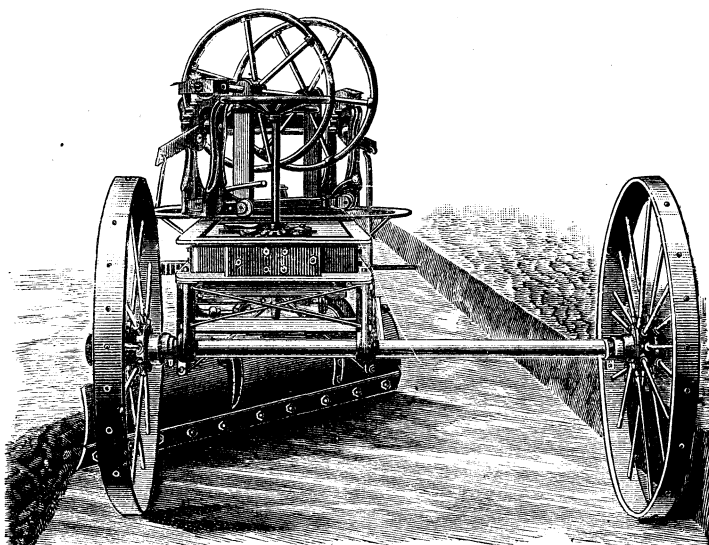


Fig. 22.—Champion road machine at work on an earth road.

rightly observed and the proper remedy applied, would doubtless put an end to the deplorable condition of thousands of miles of earth roads in the United States.

A roadmaker should not go to the other extreme and fill up ruts and holes with stone or large gravel. In many cases it would be wiser to dump such material in the river. These stones do not wear uniformly with the rest of the material, but produce bumps and ridges, and in nearly every case result in making two holes instead of one. Every hole or rut in a roadway, if not tamped full of some good material like that of which the road is constructed, will become filled with water, and finally with mud and water, and will be dug deeper and wider by each passing vehicle.

The work of maintaining earth roads will be much increased by lack of care in properly finishing the work. The labor and money spent in

rolling a newly made road may save many times that amount of labor and money in making future repairs. After the material has been placed it should not be left for the traffic to consolidate or for the rains to wash off into the ditches, but should be carefully formed and surfaced, and then, if possible, rolled. The rolling not only consolidates the material, but puts the roadbed in proper shape for travel immediately. If there is anything more trying on man or beast than to travel over an unimproved road, it must be to travel over one which has just

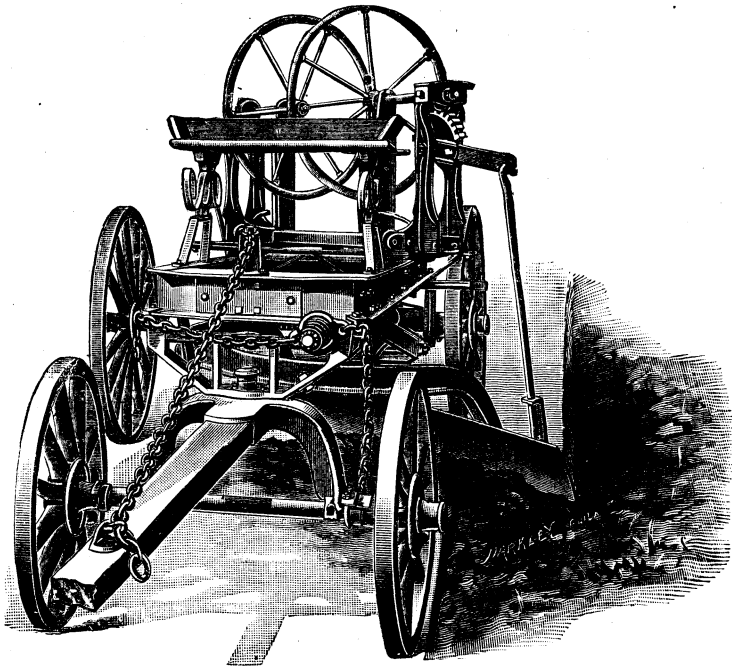


FIG. 23.—Champion road machine preparing earth road.

been “worked” by the antiquated methods now in vogue in many of the States.

**Repairs by road machines.**—The traveled way should never be repaired by the use of plows or scoops. The plow breaks up the compact surface which age and traffic has made tolerable. Earth roads can be rapidly repaired by a judicious use of road machines (figs. 22 and 23) and road rollers. The road machine places the material where it is most needed, and the roller (fig. 24) compacts and keeps it there. The labor-saving machinery now manufactured for road building is just as effectual and necessary as the modern mower, self-binder, and thrasher. Road graders and rollers are the modern inventions necessary to permanent and economical construction. Two men with two teams can build more road in one day with a grader and roller than fifty men can with picks and shovels, and do it more uniformly and more thoroughly.

**Use of wide tires.**—Doubtless the best way to keep an earth road, or any road, for that matter, in repair is by the use of wide tires (fig. 25) on all wagons carrying heavy burdens. Water and narrow tires aid each other in destroying streets, macadam, gravel, and earth roads.

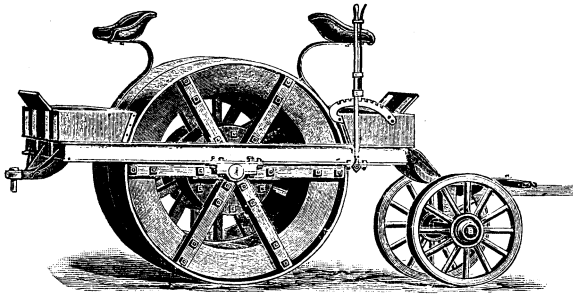


FIG. 24.—Champion reversible road roller, to be drawn by horses, and built in four different weights,  $2\frac{1}{2}$ ,  $3\frac{1}{2}$ ,  $4\frac{1}{2}$ , and  $5\frac{1}{2}$  tons.

Narrow tires are also among the most destructive agents to the fields, pastures, and meadows of farms, while on the other hand wide tires are road-makers; they roll and harden the surface, and every loaded wagon becomes in effect a

road roller. Nothing so much tends to the improving of a road as the continued rolling of its surface.

Tests recently made at the experiment stations in Utah and Missouri show that wide tires not only improve the surface of roads but that under ordinary circumstances less power is required to pull a wagon

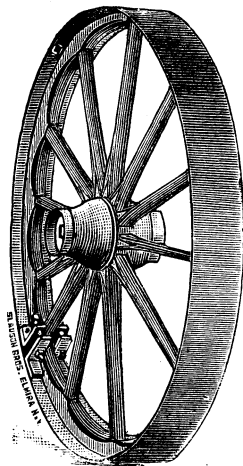


FIG. 26.—The "Richardson" adjustable tire in place on wheel of farm wagon.

on which wide tires are used. The introduction in recent years of a wide metallic tire (fig. 26), which can be placed on any narrow-tired wheel at the cost of \$2 each, has removed one very serious objection to the proposed substitution of broad tires for the narrow ones now in use.

**Time to repair roads.**—Repairs on earth roads should be attended to particularly in the spring of the year, but the great mistake of letting all the repairs go until that time should not be made. The great want of the country road

is daily care, and the sooner we do away with the system of "working out" our road taxes, and pay such taxes in money, the sooner will it be possible to build improved roads and to hire experts to keep them constantly in good repair. Roads could then secure attention when

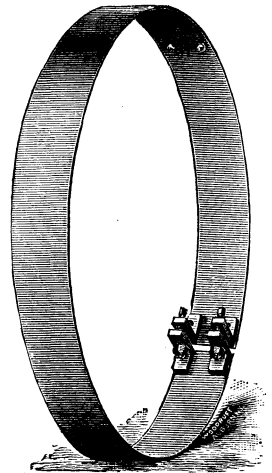


FIG. 25.—The "Richardson" adjustable wide tire.

such attention is most needed. If they are repaired only annually or semiannually they are seldom in good condition, but when they are given daily or weekly care they are most always in good condition, and, moreover, the second method costs far less than the first. A portion of all levy tax money raised for road purposes should be used in buying improved road machinery, and in constructing each year a few miles of improved stone or gravel roads.

#### **SAND ROADS.**

The only exceptions to the instructions given on road drainage is found in the attempt to improve a sand road. The more one improves the drainage of a sand road the more deplorable becomes its condition. Nothing will ruin one quicker than to dig a ditch on each side and drain all the water away. The best way to make such a road firm is to keep it constantly damp. Very bushy or shady trees alongside such roads prevent the evaporation of water.

The usual way of mending roads which run over loose sandy soils is to cover the surface with tough clay or mix the clay and sand together. This is quite an expensive treatment if the clay has to be transported a great distance, but the expense may be reduced by improving only 8 or 10 feet or half of the roadway.

#### **ROADS OF SAWDUST, TANBARK, ETC.**

Any strong, fibrous substance, and especially one which holds moisture, such as the refuse of sugar cane or sorghum, and even common straw, flax, or swamp grass will be useful. Spent tan is of some service, and wood fiber in any form is excellent. The best is the fibrous sawdust made in sawing shingles by those machines which cut lengthwise of the fiber into the side of the block. Sawdust is first spread on the road from 8 to 10 inches deep, and this is covered with sand to protect the road against fire lighted from pipes or cigars carelessly thrown or emptied on the roadbed. The sand also keeps the sawdust damp. The dust and sand soon become hard and packed, and the wheels of the heaviest wagons make but little impression upon the surface. The roadbed appears to be almost as solid as a plank road, but is much easier for the teams. The road prepared in this manner will remain good for four or five years and will then require renewing in some parts. The ordinary lumber sawdust would not be so good, of course, but if mixed with planer shavings might serve fairly well.

#### **CORDUROY ROADS.**

Roads built of poles or logs laid across the roadway are called corduroy roads, because of their corrugated or ribbed appearance. Like earth roads, they should never be built where it is possible to secure any other good material, but, as is frequently the case in swampy, timbered regions, other material is unavailable, and as the road would

be absolutely impassable without them at certain seasons of the year, it is well to know how to make them. Roads of this character should be 15 or 16 feet wide, so as to enable wagons to pass each other. Logs are superior to poles for this purpose and should be used if possible. The following in regard to the construction of corduroy roads is from Gilmore's Roads, Streets, and Pavements:

The logs are all cut the same length, which should be that of the required width of the road, and in laying them down such care in selection should be exercised as will give the smallest joints or openings between them. In order to reduce as much as possible the resistance to draft and the violence of the repeated shocks to which vehicles are subjected upon these roads, and also to render its surface practicable for draft animals, it is customary to level up between the logs with smaller pieces of the same length but split to a triangular cross-section. These are inserted with edges downward in the open joints, so as to bring their surface even with the upper sides of the large logs, or as nearly so as practicable.

Upon the bed thus prepared a layer of brush wood is put, with a few inches in thickness, with soil or turf on top to keep it in place. This completes the road. The logs are laid directly upon the natural surface of the soil, those of the same or nearly of the same diameter being kept together, and the top covering of soil is excavated from side ditches.

Cross drains may usually be omitted in roads of this kind, as the openings between the logs, even when laid with utmost care, will furnish more than ample waterway for drainage from the ditch on the upper to that on the lower side of the road. When the passage of a creek of considerable volume is to be provided for, and in localities subject to freshets, cross-drains or culverts are made wherever necessary by the omission of two or more logs, the openings being bridged with planks, split rails, or poles laid transversely to the axis of the road and resting on cross beams notched into the logs on either side.

### HARD ROADS.

The essential requirement of a good road is that it should be firm and unyielding at all times and in all kinds of weather, so that its surface may be smooth and impervious to water. Earth roads at best fulfill none of these requirements, unless they be covered with some artificial material.

On a well-made gravel road one horse can draw twice as large a load as he can on a well-made earth road. On a hard smooth stone road one horse can pull as much as four horses will on a good earth road. (Fig. 27.)

If larger loads can be hauled and better time made on good hard roads than on good earth ones, the area and the number of people benefited is increased in direct proportion to the improvement of their surface. Moreover, it is evident that a farm 4 or 5 miles from the market or shipping point located on or near a hard road is virtually nearer the market than one situated only 2 or 3 miles away, out located on a soft and yielding road. Hard roads are divided here into three classes—gravel, shell, and stone, and their construction is treated in the following pages.



FIG. 27.—Loads on macadamized road in Mecklenburg County, N. C., where formerly on earth road two bales of cotton made a good load for two mules in fairly good weather; now on macadamized road the same two mules haul ten bales of cotton in any weather.

## GRAVEL ROADS.

Although it is impracticable, and in many cases impossible, for communities to build good stone roads, a surface of gravel may frequently be used to advantage, giving far better results than could be attained by the use of earth alone. Where beds of good gravel are available this is the simplest, cheapest, and most effective method of improving country roads.

**Seaside and river gravel.**—In connection with the building and maintenance of gravel roads the most important matter to consider is that of selecting the proper material. A small proportion of argillaceous sand, clayey, or earthy matter contained in some gravel enables it to pack readily and consolidate under traffic or the road roller. Seaside and river gravel, which is composed usually of rounded, waterworn pebbles, is unfit for surfacing roads. The small stones of which they are composed having no angular projections or sharp edges, easily move or slide against each other and will not bind together, and even when mixed with clay may turn freely, causing the whole surface to be loose, like materials in a shaken sieve.

Inferior qualities of gravel can sometimes be used for foundations; but where it becomes necessary to employ such material even for that purpose it is well to mix just enough sandy or clayey loam to bind it firmly together. For the wearing surface or the top layer the pebbles should, if possible, be comparatively clean, hard, angular, and tough, so that they will readily consolidate, and will not be easily pulverized by the impact of traffic into dust and mud. They should be coarse, varying in size from half an inch to an inch and one-half.

**Blue gravel and bank gravel.**—Where blue gravel or hardpan and clean bank gravel are procurable, a good road may be made by mixing the two together. Pit gravel or gravel dug from the earth as a rule contains too much earthy matter. This may, however, be removed by sifting. For this purpose two sieves are necessary, through which the gravel should be thrown. The meshes of one sieve should be one and one-half or two inches in diameter, while the meshes of the other should be three-fourths of an inch. All pebbles which will not go through the one and one-half inch meshes should be rejected or broken so that they will go through. All material which sifts through the three-fourths inch meshes should be rejected for the road, but may be used in making side paths. The excellent road which can be built from materials prepared in this way is so far superior to the one made of the natural clayey material that the expense and trouble of sifting is many times repaid.

The best gravel for road building stands perpendicular in the bank; that is, when the pit has been opened up the remainder stands compact and firm and can not be dislodged except by use of the pick, and when it gives way falls in great chunks or solid masses. Such material

usually contains tough angular gravel with just enough cementing properties to enable it to readily pack and consolidate, and requires no further treatment than to place it properly on the prepared roadbed.

**Gravel on earth roads.**—Some earth roads may be greatly improved by covering the surface with a layer of 3 or 4 inches of gravel, and sometimes even a thinner layer may prove of very great benefit if kept in proper repair. The subsoil of such roadway ought, however, to be well drained, or of a light and porous nature. Roads constructed over clay soils require a layer of at least 6 inches of gravel. The gravel must be deep enough to prevent the weight of traffic forcing the surface material into weak places in the clay beneath, and also to prevent the surface water from percolating through and softening the clay and causing the whole roadway to be torn up.

Owing to a lack of knowledge regarding construction, indifference, or carelessness in building or improving, roads made of gravel are often very much worse than they ought to be. Some of them are made by simply dumping the material into ruts, mud holes, or gutter-like depressions, or on unimproved foundation, and are left thus for traffic to consolidate; while others are made by covering the surface with inferior material without any attention being paid to the fundamental principles of drainage. As a result of such thoughtless and haphazard methods the road usually becomes rougher and more completely covered with holes than before.

**Grade and width of gravel roads.**—In constructing a gravel road the roadbed should first be brought to the proper grade. Ordinarily an excavation is then made to the depth of 8 or 10 inches, varying in width with the requirements of traffic. For a farm or farming community the width need not be greater than 10 or 12 feet. A roadway which is too wide is not only useless, but the extra width is a positive damage. Any width beyond that needed for the traffic is not only a waste of money in constructing the road, but is the cause of a never-ending expense in maintaining it. The surface of the roadbed should preferably have a fall from the center to the sides the same as that to be given the finished road, and should, if possible, be thoroughly rolled and consolidated until perfectly smooth and firm.

A layer, not thicker than 4 inches, of good gravel, such as that recommended above, should then be spread evenly over the prepared roadbed. Such material is usually carried upon a road in wheelbarrows or dumpcarts, and then spread in even layers with rakes, but the latest and best device for this purpose is a spreading cart (fig. 36).

**Rolling the road.**—If a roller can not be had, the road is thrown open to traffic until it becomes fairly well consolidated; but it is impossible to properly consolidate materials by the movement of vehicles over the road, and if this means is pursued constant watchfulness is necessary to prevent unequal wear and to keep the surface smooth and free from ruts. The work may be hastened and facilitated by the use of a horse

roller (fig. 28) or light steam roller (fig. 29); and of course far better results can be accomplished by this means. If the gravel be too dry to consolidate easily it should be kept moist by sprinkling. It should not, however, be made too wet, as any earthy or clayey matter in the gravel is liable to be dissolved.

As soon as the first layer has been properly consolidated a second, third and, if necessary, fourth layer, each 3 or 4 inches in thickness, is spread on and treated in the same manner, until the road is built up to the required thickness and cross section. The thickness in most cases need not be greater than 10 or 12 inches, and the fall from the center to the sides ought not to be greater than 1 foot in 20 feet, or less than 1 in 25.

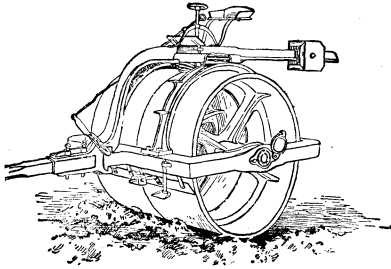


FIG. 28.—The Austin reversible horse roller, provided with roller bearings to lighten draft, and weight plates for increasing weight.

The last or surface layer should be rolled until the wheels of heavily loaded vehicles passing over it make no visible impression. If the top layer is deficient in binding material and will not properly consolidate, a thin layer, not exceeding one inch in thickness, of sand or gravelly loam or clay should be evenly spread on and slightly sprinkled if in dry weather, before the rolling is begun. Hardpan or stone screenings are much preferred for this purpose if they can be had.

The tendency of the material to spread under the roller and work toward the sides can be resisted by rolling that portion nearest the gutters first. To give the surface the required form and to secure uniform density, it is necessary at times to employ men with rakes to fill any depressions which may form.

**Maintenance.**—In order to maintain a gravel road in good condition, it is well to keep piles of gravel (fig. 30) alongside at frequent intervals, so that the person who repairs the road can get the material without going too far for it. As soon as ruts or holes appear on the surface some of this good fresh material should be added and tamped into position or kept raked smooth until properly consolidated.

If the surface needs replenishing or rounding up, as is frequently the case with new roads after considerable wear, the material should be applied in sections or patches, raked and rolled until hard and smooth.

Care must be taken that the water from higher places does not drain

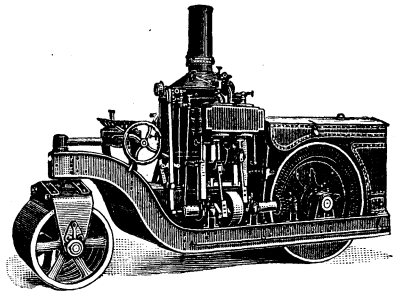


FIG. 29.—Iroquois steam road roller, built in all sizes.

onto or run across the road. The side ditches, culverts, and drains should be kept open and free from *débris*.

### SHELL ROADS.

In many of the Eastern and Southern States road stones do not exist; neither is it possible to secure good coarse gravel. No such material can be secured except at such an expense for freight as to practically preclude its use for road building. Oyster shells can be secured cheaply in most of these States, and when applied directly upon sand or sandy soil, 8 or 10 inches in thickness, they form excellent roads for pleasure driving and light traffic. Shells wear much more rapidly than broken stone or gravel of good quality, and consequently roads made of them require more constant attention to keep them in good order. In most cases they should have an entirely new surface every three or four

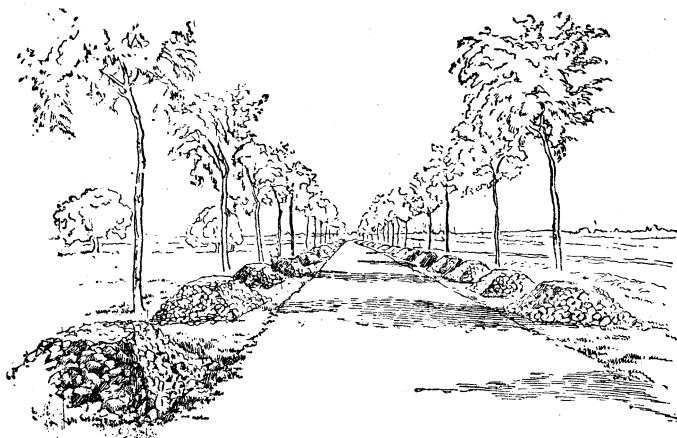


FIG. 30.—Road in France between Fontainebleau and Sens, illustrating method of placing stone and gravel for repaving and resurfacing, and the planting of trees at a safe distance from the roadside.

years. When properly maintained they possess many of the qualities found in good stone or gravel roads, and so far as beauty is concerned they can not be surpassed.

### STONE ROADS.

The greatest obstacles to good stone road construction in most places in the United States are the existing methods of building and systems of management, whereby millions of dollars are annually wasted in improper construction or in making trifling repairs on temporary structures.

The practice of using too soft, too brittle, or rotten material on roads can not be too severely condemned. Some people seem to think that if a stone quarries easily, breaks easily, and packs readily, it is the very best stone for road building. This practice, together with that of plac-

ing the material on unimproved foundations and leaving it thus for traffic to consolidate, has done a great deal to destroy the confidence of many people in stone roads. There is no reason in the world why a road should not last for ages if it is built of good material and kept in proper repair. If this is not done the money spent is more than wasted. It is more economical, as a rule, to bring good materials a long distance by rail or water than to employ inferior ones procured close at hand.

The durability of roads depends largely upon the power of the materials of which they are composed to resist those natural and artificial forces which are constantly acting to destroy them. The fragments of which they are constructed are liable to be attacked in cold climates by frost, and in all climates by water and wind. If composed of stone or gravel the particles are constantly grinding against each other and being exposed to the impact of the tires of vehicles and the feet of animals. Atmospheric agencies are also at work decomposing and disintegrating the material. It is obviously necessary, therefore, that great care be exercised in selecting for the surfacing of roads those stones which are less liable to be destroyed or decomposed by these physical, dynamical, and chemical forces.

**Useful stones for road building.**—Siliceous materials, those composed of flint or quartz, although hard, are brittle and deficient in toughness. Granite is not desirable because it is composed of three materials of different natures, viz: quartz, feldspar, and mica, the first of which is brittle, the second liable to decompose rapidly, and the third laminable or of a scaly or layerlike nature. Some granites which contain hornblende instead of feldspar are desirable. The darker the variety the better. Gneiss, which is composed of quartz, feldspar, and mica, more or less distinctly slaty, is inferior to granite. Mica-slate stones are altogether useless. The argillaceous slates or clayey slates make a smooth surface, but one which is easily destroyed when wet. The sandstones are utterly useless for road building. The tougher limestones are very good, but the softer ones, though they bind and make a smooth surface very quickly, are too weak for heavy loads; they wear, wash, and blow away very rapidly.

The materials employed for surfacing roads should be both hard and tough, and should possess by all means cementing and recementing qualities. For the Southern States, where there are no frosts to contend with, the best qualities of limestone are considered quite satisfactory so far as the cementing and recementing qualities are concerned, but in most cases roads built of this class of material do not stand the wear and tear of traffic like those built of trap rock, and when exposed to the severe northern winters such material disintegrates very rapidly. In fact, trap rock, "nigger heads," technically known as diabase, and diorites, are considered by most road engineers of long experience to be the very best stones for road building. Trap rocks as a rule possess

all the qualities most desired for road stones. They are hard and tough, and when properly broken to small sizes and rolled thoroughly, cement and consolidate into a smooth, hard crust which is impervious to water, and the broken particles are so heavy that they are not readily blown or washed away.

Unfortunately the most useful stones for road building are the most difficult to prepare, and as trap rocks are harder to break than any other stones they usually cost more. The foundation or lower courses may be formed of some of the softer stones, like gneiss or limestone, but trap rock should be used for the wearing surface, if possible, even if it has to be brought from a distance.

As to construction of macadam roads, Mr. Potter says:

In the construction of a macadam road in any given locality, the question of economy generally compels us to use a material found near at hand, and where a

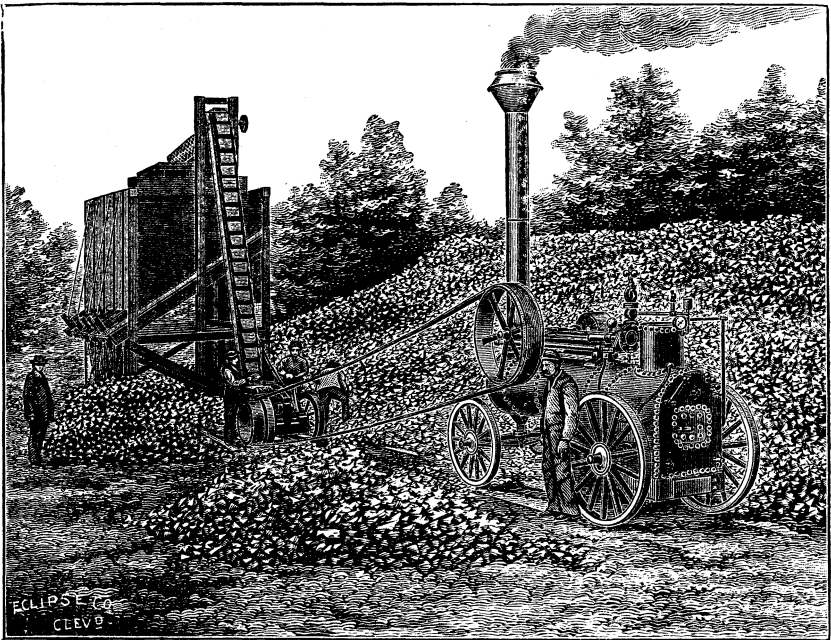


FIG. 31.—Complete Climax crushing plant in operation at Towanda, Pa.

local quarry does not exist field stone and stone gathered from the beds of rivers and small streams may often be made to serve every purpose. Many of the stones and boulders thus obtained are of trap rock, and in general it may be said that all hard field and river stones, if broken to a proper size, will make fairly good and sometimes very excellent road metal. No elaborate test is required to determine the hardness of any given specimen. A steel hammer in the hands of an intelligent workman will reveal in a general way the relative degree of toughness of two or more pieces of rock. Field and river stone offer an additional advantage in that they are quickly handled, are generally of convenient size, and are more readily broken either by hand or by machine than most varieties of rock which are quarried in the usual way.

It is a simple task to break stone for macadam roadways, and by the aid of modern inventions it can be done cheaply and quickly. Hand-broken stone is fairly out of date and is rarely used in America where any considerable amount of work is to be undertaken. Stone may be broken by hand at different points along the roadside

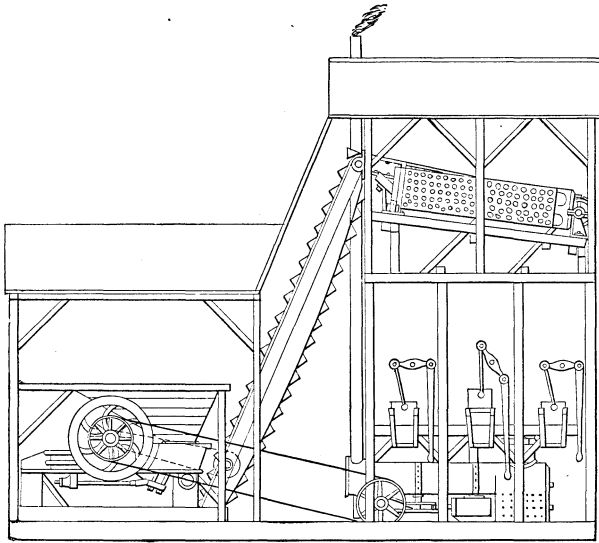


FIG. 32.—Stationary crushing plant. Elevator, screen, and bunkers complete.

where repairs are needed from time to time, but the extra cost of production by this method forbids its being carried on where extended work is undertaken. Hand-broken stone is generally more uniform in size, more nearly cubical in shape, and

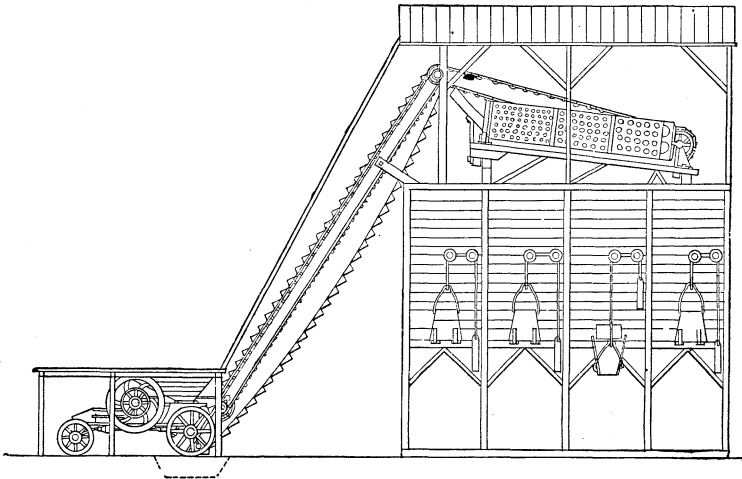


FIG. 33.—Semistationary crushing plant. Elevators, screen, and bunkers complete.

has sharper angles than that broken by machinery, but the latter, when properly assorted or screened, has been found to meet every requirement.

**Stone crushers.**—A good crusher (fig. 31) driven by eight horsepower will turn out

from forty to eighty cubic yards of 2-inch stone per day of ten hours, and will cost from \$400 upward, according to quality.

Some crushers are made either stationary (see fig. 32), semi-stationary (fig. 33), or portable (fig. 34), according to the needs of the purchaser, and for country-road work it is sometimes very desirable to have a portable crusher to facilitate its easy transfer from one part of the town to another. The same portable engine that is used in thrashing, sawing wood, and other operations requiring the use of steam

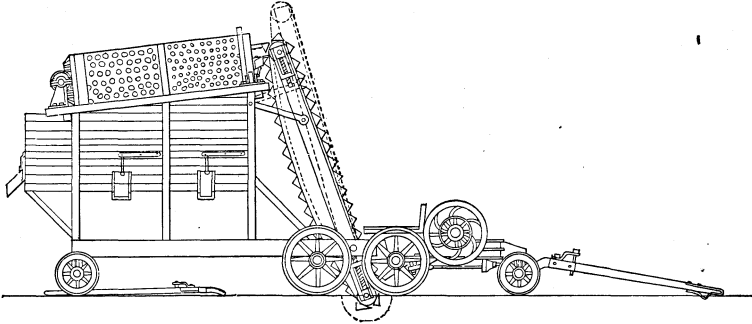


FIG. 34.—Portable crushing plant. Elevator, screen, and bunkers complete.

power may be used in running a stone crusher, but it is best to remember that a crusher will do its best and most economical work when run by a machine having a horsepower somewhat in excess of the power actually required.

**Screening the stone.**—As the stone comes from the breaker the pieces will be found to show a considerable variety in size, and by many practical roadmakers it is regarded as best that these sizes should be assorted and separated, since each has its particular use. To do this work by hand would be troublesome and expensive, and

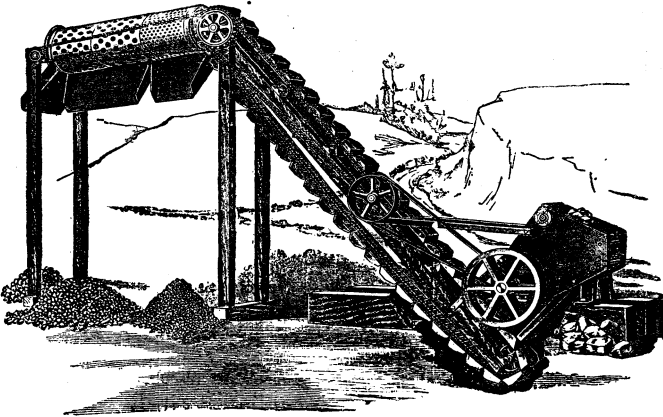


FIG. 35.—Stationary Champion rock crusher, showing apparatus for separating stone into proper sizes.

screens are generally employed for that purpose. Screens are not absolutely necessary, and many roadmakers do not use them; but they insure uniformity in size of pieces, and uniformity means in many cases superior wear, smoothness, and economy. Most of the screens in common use to-day are of the rotary kind. In operating, they are generally so arranged that the product of the crusher falls directly into the rotary screen, which revolves on an inclined axis and empties the separate pieces into small bins below the crusher. A better form (fig. 35) for many purposes includes

a larger and more elaborate outfit, in which the stone is carried by an elevator to the screen and by the screen emptied into separate bins (figs. 32, 33, and 34) according to the respective sizes. From the bins it is easily loaded into wagons or spreading carts (fig. 36) and hauled to any desired point along the line of the road.

The size to which stone should be broken depends upon the quality of the stone,

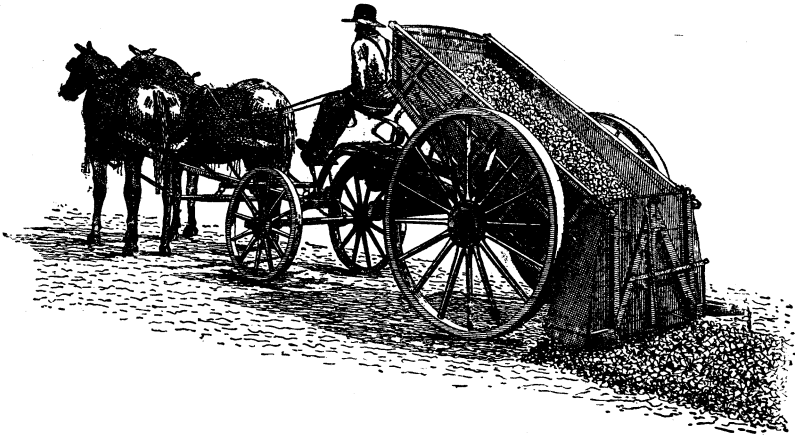


FIG. 36.—Champion distributing cart in operation.

the amount of traffic to which the road will be subjected, and to some extent upon the manner in which the stone is put in place. If a hard tough stone is employed it may be broken into rough cubes or pieces of about  $1\frac{1}{2}$  inches in largest face dimensions, and when broken to such a size the product of the crusher may generally be used to good advantage without the trouble of screening, since dust "tailings" and fine stuff do not accumulate in large quantities in the breaking of the tougher stone.



FIG. 37.—John L. Macadam.

If only moderate traffic is to be provided for the harder limestones may be broken so the pieces will pass through a 2-inch ring, though sizes running from  $2\frac{1}{4}$  to  $2\frac{1}{2}$  inches will insure a more durable roadway, and if a steam roller is used in compacting the metal it will be brought to a smooth surface without much trouble. As a rule it may be said that to adhere closely to a size running from  $2\frac{1}{4}$  to  $2\frac{1}{2}$  inches in largest face dimensions, and to use care in excluding too large a proportion of small stuff as well as all pieces of excessive size, will insure a satisfactory and durable macadam road.

Macadam insisted that no large stone should ever be employed in road making, and, indeed, most modern road builders practice his principle that "small angular fragments are the cardinal requirements." As a general rule it has been stated that no stone larger than a walnut should be used for the surfacing of roads.

**The macadam and telford methods.**—Stone roads are built in most cases according to the principles laid down by John L. Macadam (fig. 37), while some are built by the methods advocated by Telford. The most important difference between these two principles of construction relates to the propriety or necessity of a paved foundation beneath the crust of broken stone. Telford advocated this principle, while Macadam strongly denied its advantages.

In building roads very few iron-clad rules can be laid down for universal application; skill and judgment must be exercised in designing



FIG. 38.—Cross section of macadam road showing a compact foundation of earth supporting a solid and durable stone surface.

and building each road so that it will best meet the requirements of the place it is to occupy. The relative value of the telford and macadam systems can most always be determined by the local circumstances, conditions, and necessities under which the road is to be built. The former system seems to have the advantage in swampy, wet places, or where the soil is in strata varying in hardness, or where the foundation is liable to get soft in spots. Under most other circumstances experienced road builders prefer the macadam construction, not only because it is considered best, but also because it is much cheaper.

**Macadam construction.**—The macadam road (fig. 38) consists of a mass of angular fragments of rock deposited usually in layers upon the road-bed or prepared foundation and consolidated to a smooth, hard surface produced by the passage of vehicles or by use of a road roller (fig. 39). The thickness of this crust varies with the soil, the nature of the stone used, and the amount of traffic which the road is expected to have. It should be so thick that the greatest load will not affect the foundation. The weight usually comes upon a very small part of the surface, but is spread over a large area of the foundation, and the thicker the crust the more uniformly will the load be distributed over the foundation.

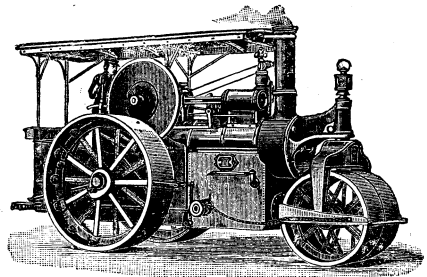


FIG. 39.—Buffalo Pitts steam road roller, sizes, 10, 12, and 15 tons.

Macadam earnestly advocated the principle that all artificial road building depended wholly for its success upon the making and maintaining of a solid dry foundation and the covering of this foundation with a durable waterproof coating or roof of broken stone. The foundation must be solid and firm; if it be otherwise the crust is use-

less. A road builder should always remember that without a durable foundation there is no durable road. Hundreds of miles of macadam roads are built in the United States each year on unimproved or unstable foundations and almost as many miles go to pieces for this same reason. Says Macadam:

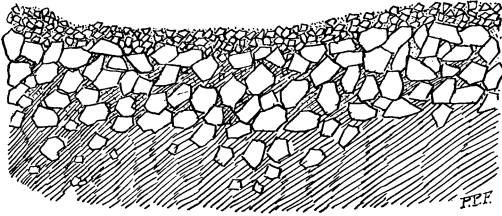


FIG. 40.—Cross section of macadam road showing result of placing stone on loose or wet earth foundation.

The stone is employed to form a secure, smooth, water-tight flooring, over which vehicles may pass with safety and expedition at all seasons of the year.

Its thickness should be regulated only by the quality of the material necessary to form such a flooring and not at all by any consideration as to its own independent power of bearing weight. \* \* \* The erroneous idea that the evils of an underdrained, wet, clayey soil can be remedied by a large quantity of materials has caused a large part of the costly and unsuccessful expenditures in making stone roads.

**Application of the material.**—The evils from improper construction of stone roads are even greater than those resulting from the use of



FIG. 41.—Bad condition of road resulting from attempt at macadam construction with large and small broken stone. Large stones have worked out to the surface (drawn from photograph).

improper material. Macadam never intended that a heterogeneous conglomeration of stones and mud (fig. 40) should be called a macadam road. The mistake is often made of depositing broken stone on an old road without first preparing a suitable foundation. The result, in

most cases, is that the dirt and mud prevent the stone from packing and by the action of traffic ooze to the surface, while the stones sink deeper and deeper, leaving the road as bad as before.

Another great mistake is often made of spreading large and small stones over a well-graded and well-drained foundation and leaving



FIG. 42.—Excavating and preparing roadbed for macadam surface (drawn from photograph).

them thus for traffic to consolidate. (See fig. 41.) The surface of a road left in this manner is often kept in constant turmoil by the larger stones, which work themselves to the surface and are knocked hither and thither by the wheels of vehicles and the feet of animals. These plans of construction can not be too severely condemned.

The roadbed (fig. 42) should be first graded, then carefully surface-drained. The earth should then be excavated to the depth to which material is to be spread on, and the foundation properly shaped and sloped each way from the center so as to discharge any water which may percolate through. This curvature should conform to the curvature of the finished road. A shouldering of firm earth or gravel should be left or made on each side to hold the material in place, and should extend to the gutters at the same curvature as the finished road. The foundation should then be rolled until hard and smooth.

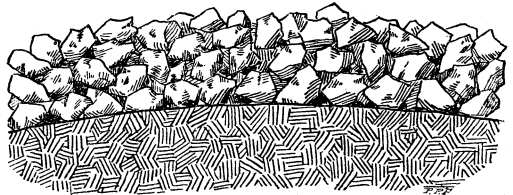


FIG. 43.—First course of stone on a macadam road as it appears when spread ready for rolling.

Upon this bed spread a layer of 3 or 4 inches of broken stone, which

stone should be free from any earthy mixture. This layer should be thoroughly rolled until compact and firm (figs. 43, 44, 45). Stone may be hauled from the stone-crusher bins or from the stone piles in ordinary wheelbarrows or farm wagons, and should be distributed broadcast over the surface with shovels, and all inequalities leveled up by the use of rakes. If this method of spreading is employed, grade stakes should be used so as to insure a uniformity of thickness. After the stakes are driven the height of the layer is marked on their sides, and if thought necessary a piece of stout cord is stretched from stake

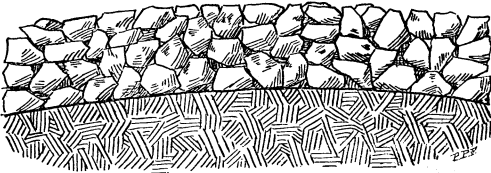


FIG. 44.—First course of stone on a macadam road when partially rolled, showing how the roller packs it.

to stake, showing the exact height to which the layer should be spread. Spreading carts (fig. 36) have been recently invented which not only place the stone where it is needed without the use of shovels, but spread it on in layers of

any desired thickness and at the same time several inches wider than the carts themselves.

If the stones have been separated into two or three different sizes the largest size should compose the bottom layer, the next size the second layer, etc. The surface of each course or layer should be thoroughly and repeatedly rolled and sprinkled until it becomes firm, compact, and smooth. The first layer, however, should not be sprinkled as the water is liable to soften the foundation. The rolling ought to be done along the side lines first, gradually working toward the center as the job is being completed. In rolling the last course it is well to begin by rolling first the shoulderings or the side roads if such exist.

A coat of three-quarter inch stone and screenings, of sufficient thickness to make a smooth and uniform surface, should compose the last course, and, like the other layers, should be rolled until perfectly firm and smooth. As a final test of perfection, a small stone placed on the surface will be crushed before being driven into the material.

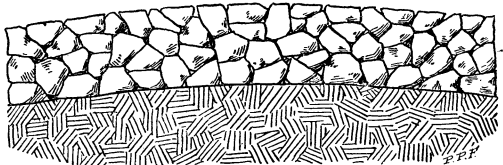


FIG. 45.—Stone on a macadam road firmly wedged and packed together. Small stones, gravel, dirt, or sand if mixed with the stone or spread on the surface before rolling, prevent its being thoroughly wedged and packed.

If none of the stones used be larger than will pass through a 2-inch ring they can be spread on in layers as above described without separating them by screens. Water and binding material—stone screenings or good packing gravel—can be added if found necessary for proper consolidation. Earth or clay should never be used for a binding mate-

rial. Enough water should be sprinkled on to wash in and fill all voids between the broken stones with binding material, and to leave such material damp enough to insure a set.

**Rollers.**—If a road is built of tough, hard stone, and if the binding material has the same characteristics, a steam roller (fig. 39) is essential for speedy results. A horse roller (fig. 46) may be used to good advantage if the softer varieties of stone are employed. For general purposes, a roller weighing from 8 to 12 tons is all that is necessary. Heavier weights are difficult to handle upon unimproved surfaces unless they be constructed like the one shown in fig. 46, the weight of which can be increased or lightened at will by filling the drum with water or drawing the water out. This roller can be made to weigh as much as 8 tons and, like several other very excellent ones now on the market, is provided with antifriction roller bearings, which lighten the draft considerably.

**Binding material.**—Every stone road, unless properly built with small stones and just enough binding material to fill the voids, presents a honeycombed appearance. In fact, a measure containing 2 cubic feet of broken stone will hold in addition 1 cubic foot of water, and a cubic yard of broken macadam will weigh just about one-half as much as a solid cubic yard of the same kind of stone. Isaac Potter says:

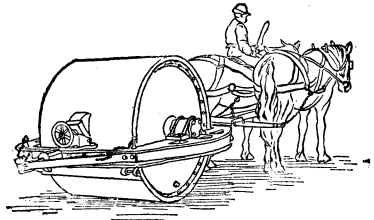


FIG. 46.—The Addison reversible horse roller, the weight of which can be increased by filling the roller with water.

To insure a solid roadway and to fill the large proportion of voids or interstices between the different pieces of broken stone some finer material must be introduced into the structure of the roadway, and this material is usually called a binder, or by some roadmakers a "filler."

There used to be much contention regarding the use of binding material in the making of a macadam road, but it is now conceded by nearly all practical and experienced roadmakers, both in Europe and America, that the use of a binding material is essential to the proper construction of a good macadam road. It adds to its solidity, insures tightness by closing all of the spaces between the loose irregular stones, and binds together the macadam crust in a way that gives it firmness, elasticity and durability.

Binding material to produce the best results should be equal in hardness and toughness with the road stone; the best results are therefore obtained by using screenings or spalls from the broken stone used. Coarse sand or gravel can sometimes be used with impunity as a binder, but the wisdom of using loam or clay is very much questioned. When the latter material is used for a binder the road is apt to become very dusty in dry weather, and sticky, muddy, and ratty in wet weather.

**Telford construction.**—The character of the foundation should never take the place of proper drainage. The advisability of underground

or subdrainage should always be carefully considered where the road is liable to be attacked from beneath by water. In most cases good subdrains will so dry the foundation out that the macadam construction can be resorted to. Sometimes, however, thorough drainage is difficult or doubtful, and in such cases it is desirable to adopt some heavy construction like the telford; and furthermore the difficulty of procuring perfectly solid and reliable roadbeds in many places is often overcome by the use of this system.

In making a telford road (fig. 47) the surface for the foundation is prepared in the same manner as for a macadam road. A layer of broken stone is then placed on the roadbed from 5 to 8 inches in depth, depending upon the thickness to be given the finished road. As a rule this foundation should form about two-thirds of the total thickness of the material. The stone used for the first layer may vary in thickness from 2 to 4 inches and in length from 8 to 12 inches. The thickness of the upper edges of the stones should not exceed 4 inches. They are set by hand on their broadest edges lengthwise across the road, breaking joints as much as possible. All projecting points are then broken off and the interstices or cracks filled with stone chips,

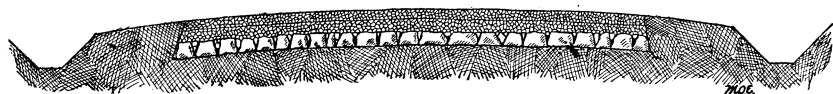


FIG. 47.—Transverse section of telford road with macadam surface.

and the whole structure wedged and consolidated into a solid and complete pavement. Upon this pavement layers of broken stones are spread and treated in the same way as for a macadam road.

**Stone road maintenance.**—Stone roads should be frequently scraped, so as to remove all dust and mud. Nothing destroys a stone road quicker than dust or mud. The hand method of scraping with a hoe is considered best. No matter how carefully adjusted the machinery built for this purpose may be, it is liable to ravel a road by loosening some of the stones. The gutters and surface drains should be kept open, so that all water falling upon the road or on the adjacent ground may promptly flow away. Says Spalding, a road authority:

If the road metal be of soft material which wears easily, it will require constant supervision and small repairs whenever a rut or depression may appear. Material of this kind binds readily with new material that may be added, and may in this manner frequently be kept in good condition without great difficulty, while if not attended to at once when wear begins to show it will very rapidly increase, to the great detriment of the road. In making repairs by this method, the material is commonly placed a little at a time and compacted by passing vehicles. The material used for this purpose should be the same as that of the road surface and not fine material, which would soon reduce to powder under the loads which come upon it. By careful attention to minute repairs in this manner a surface may be kept in good condition until it wears so thin as to require renewal.

In case the road be of harder material, that will not so readily combine when a thin coating is added, repairs may not be frequent, as the surface will not wear so

rapidly and immediate attention is not so important. It is usually more satisfactory in this case to make more extensive repairs at one time, as a larger quantity of material added at once may be more readily compacted to a uniform surface, the repairs taking the form of an additional layer upon the road.

Where the material of the road surface is very hard and durable, a well-constructed road may wear quite evenly and require hardly any attention, beyond ordinary small repairs, until worn out. It is now usually considered the best practice to leave such a road to itself until it wears very thin, and then renew it by an entirely new layer of broken stone placed in the worn surface and without in any way disturbing that surface.

If a thin layer only of material is to be added at one time, in order that it may unite firmly with the upper layer of the road, it is usually necessary to break the bond

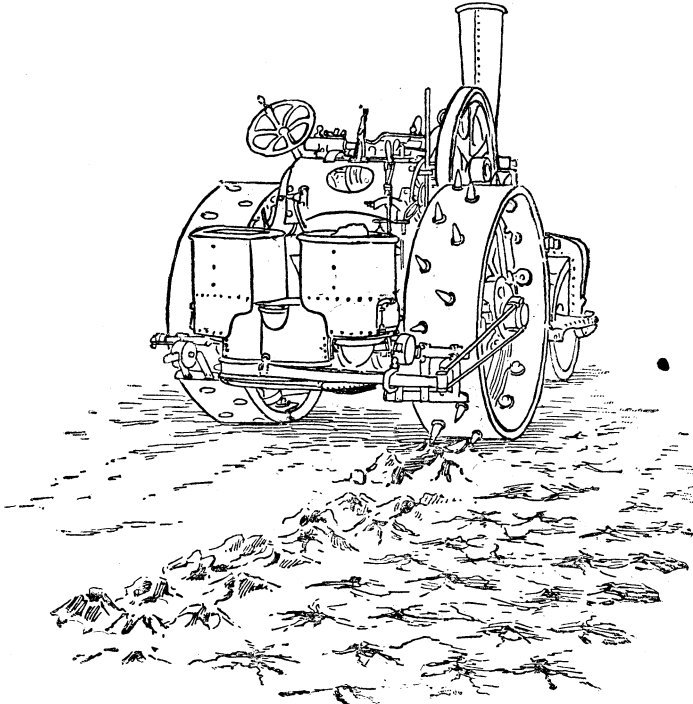


FIG. 48.—Steam roller with spikes in wheel breaking up road surface.

of the surface material before placing the new layer, either by picking it up by hand or by a steam roller with short spikes in its surface (fig. 48), if such a machine is at hand. Care should be taken in doing this, however, that only the surface layer be loosened, and that the solidity of the body of the road be not disturbed, as might be the case if the spikes are too long.

In repairing roads the time-honored custom of waiting until the road has lost its shape or until the surface has become filled with holes or ruts should never be tolerated. Much good material is wasted by spreading a thick coat over such a road and leaving it thus for passing vehicles to consolidate. The material necessary to replace defects in a road should be added when the necessities arise and should be of the best quality and the smallest possible quantity. If properly laid in

small patches the inconvenience to traffic will be scarcely perceptible. If such repairs are made in damp weather, as they ought to be, little or no difficulty is experienced in getting a layer of stone to consolidate properly. If mud fills the rut or hole to be repaired, it should be carefully removed before the material is placed.

Wide tires should be used on all heavy vehicles which traverse stone roads (fig. 49). A four or five inch stone or gravel road will last longer

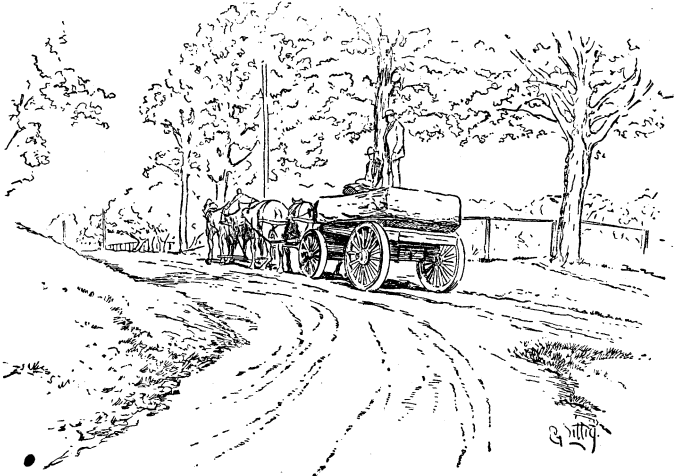


FIG. 49.—Hauling 9 tons of stone on wide-tired wagon over road in Onondaga County, N. Y. (drawn from photograph).

without repair when wide tires are used than an eight or ten inch road of the same material on which narrow tires are used.

### TREES ALONGSIDE OF ROADS.

Not only should brush and weeds be removed from the roadside, but grass should be sown, trees planted, and a side path or walk be prepared for the use of women, children, and other pedestrians going to and coming from church, school, and places of business and amusement. Country roads can be made far more useful and attractive than they usually are, and this may be secured by the expenditure of only a small amount of labor and money. Although such improvements are not necessary, they make the surroundings attractive and inviting, and add to the value of property and the pleasure of the traveler.

If trees are planted alongside the road they should be far enough back to admit the wind and sun (fig. 30.) Most strong growing trees are apt to extend their roots under the gutters and even beneath the roadway if they are planted too close to the roadside. Even if they be planted at a safe distance those varieties should be selected which send their roots downward rather than horizontally. The most useful and beautiful tree corresponding with these requirements is the chestnut, while certain varieties of the pear, cherry, and mulberry answer the same purpose. Where there is no danger of roots damaging the sub-

drainage or the substructure of the road some other favorite varieties would be elms, rock maples, horse-chestnuts, beeches, pines, and cedars. Climate, variety of species selected, and good judgment will determine the distance between such trees. Elms should be 30 feet apart, while the less spreading varieties need not be so far. The trunks should be trimmed to a considerable height, so as to admit the sun and air. Fruit trees are planted along the roadsides in Germany and Switzerland, while mulberry trees may be seen along the roads in France, serving the twofold purpose of food for silkworms and shade. If some of our many varieties of useful, fruitful, and beautiful trees were planted along the roads in this country, and if some means could be devised for protecting the product, enough revenue could be derived therefrom to pay for the maintenance of the road along which they throw their grateful shade.

### **COST OF ROADS.**

The improvement of country roads is chiefly an economical question, relating principally to the waste of effort in hauling over bad roads, the saving in money, time, and energy in hauling over good ones, the initial cost of improving roads, and the difference in the cost of maintaining good and bad ones. It is not necessary to enlarge on this subject in order to convince the average reader that good roads reduce the resistance to traffic, and consequently the cost of transportation of products and goods to and from farms and markets is reduced to a minimum.

The initial cost of a road depends upon the cost of materials, labor, machinery, the width and depth to which the material is to be spread on, and the method of construction. All these things vary so much in the different States that it is impossible to name the exact amount for which a mile of a certain kind of road can be built.

The introduction in recent years of improved road-building machinery has enabled the authorities in some of the States to build improved stone and gravel roads quite cheaply. First class single-track stone roads, 9 feet wide, have been built near Canandaigua, N. Y., for \$900 to \$1,000 per mile. Many excellent gravel roads have been built in New Jersey for \$1,000 to \$1,300 per mile. The material of which they were constructed was placed on in two layers, each being raked and thoroughly rolled, and the whole mass consolidated to a thickness of 8 inches. In the same State macadam roads have been built for \$2,000 to \$5,000 per mile, varying in width from 9 to 20 feet and in thickness of material from 4 to 12 inches. Telford roads 14 feet wide and 10 to 12 inches thick have been built in New Jersey for \$4,000 to \$6,000 per mile. Macadam roads have been built at Bridgeport and Fairfield, Conn., 18 to 20 feet wide, for \$3,000 to \$5,000 per mile. A telford road 16 feet wide and 12 inches thick was built at Fanwood, N. J., for \$9,500 per mile. Macadam roads have been built in Rhode Island, 16 to 20 feet wide, for \$4,000 to \$5,000 per mile.

Massachusetts roads are costing all the way from \$6,000 to \$25,000 per mile. A mile of broken stone road, 15 feet wide, costs in the State of Massachusetts about \$5,700 per mile, while a mile of the same width and kind of road costs in the State of New Jersey only \$4,700. This is due partly to the fact that the topography of Massachusetts is somewhat rougher than that of New Jersey, necessitating the reduction of many steep grades and the building of expensive retaining walls and bridges, and partly to the difference in methods of construction and the difference in prices of materials, labor, etc.

Doubtless the State of New Jersey is building more roads and better roads for less money per mile than any other State in the Union. Their roads are now costing from 20 to 70 cents per square yard. Where the telford construction is used they sometimes cost as much as 73 cents per square yard. The average cost of all classes of the roads of that State during the last season was about 50 cents per square yard. The stone was, as a rule, spread on to a depth of 9 inches, which, after rolling, gave a depth of about 8 inches. At this rate a single-track road 8 feet wide costs about \$2,346 per mile, while a double-track road 14 feet wide costs about \$4,106 per mile, and one 18 feet wide costs about \$5,280 per mile. Where the material is spread on so as to consolidate to a 4-inch layer the 8-foot road will cost about \$1,173 per mile, the 14-foot road about \$2,053 per mile, while the one 18 feet wide will cost about \$2,640 per mile.

The total cost of maintaining roads in good order ranges, on account of varying conditions, between as wide limits almost as the initial cost of construction. Suffice it to say that all money spent on repairing earth roads becomes each year a total loss without materially improving their condition. They are, as a rule, the most expensive roads that can be used, while on the other hand stone roads, if properly constructed of good material and kept in perfect condition, are the most satisfactory, the cheapest, and most economical roads that can be constructed.

### CONCLUSION.

The road that will best suit the needs of the farmer, in the first place, must not be too costly; and, in the second place, must be of the very best kind, for farmers should be able to do their heavy hauling over them when their fields are too wet to work and their teams would otherwise be idle.

The best road for the farmer, all things being considered, is a solid, well-built stone road, so narrow as to be only a single track, but having a firm earth road on one or both sides. Where the traffic is not very extensive the purposes of good roads are better served by narrow tracks than by wide ones, while many of the objectionable features of wide tracks are removed, the initial cost of construction is cut down one-half or more, and the charges for repair reduced in proportion.

## FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C. Only the following are available for distribution:

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